

GENOTYPE x ENVIRONMENT INTERACTIONS OF
TRITICALE IN FLORIDA

By

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To the God I know too little of,
To the sons I knew too briefly,
 and
To Diane, my love and my friend.

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TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGMENTS.....	iii
LIST OF TABLES.....	v
LIST OF FIGURES.....	vii
ABSTRACT.....	viii
INTRODUCTION.....	1
MATERIALS AND METHODS.....	7
Analysis of Pure Lines.....	8
Analysis of Blends.....	10
RESULTS.....	12
Stability of Pure Lines.....	12
Grain Yield.....	12
Kernel Weight.....	18
Tiller Number.....	22
Plant Height.....	24
Test Weight.....	26
Kernel Number per Tiller.....	28
Stability of Blends.....	28
Grain Yield.....	28
Test Weight.....	34
DISCUSSION.....	38
Pure Lines.....	38
Blends.....	48
APPENDIX	
DATA TABLES.....	52
REFERENCES.....	58
BIOGRAPHICAL SKETCH.....	62

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Mean squares for the analysis of variance and regression partition for grain yield (GY), kernel weight (KW), and tiller number (TN), and plant height (PH).....	13
2. Mean grain yield (GY), kernel weight (KW), tiller number (TN), plant height (PH), and test weight (TW) of six triticale genotypes by year, location and N level.....	14
3. Stability parameters [mean, regression coefficient ($\bar{b}$), and deviation mean square (DMS)] for grain yield (GY), kernel weight (KW), tiller number (TN), plant height (PH), and test weight (TW) of six hexaploid triticale genotypes.....	15
4. Means and regression coefficients ($\bar{b}$) of six triticale genotypes in above average and below average environments.....	17
5. Simple correlation coefficients between stability parameters [regression coefficient ($\bar{b}$) and deviation mean square (DMS)] for grain yield (GY) and other traits [kernel weight (KW), tiller (TN), plant height (PH), and test weight (TW)].....	19
6. Simple correlation coefficients among kernel weight (KW), tiller number (TN), and Kernel number per tiller (KN) by genotype.....	20
7. Simple correlation coefficients among kernel weight (KW), tiller number (TN), and kernel number per tiller (KN) (as a proportion of their environmental means) by genotype.....	21
8. Mean squares for the analysis of variance and regression partition for test weight of six triticale genotypes.....	27

<u>Table</u>	<u>Page</u>
9. Mean squares ($\times 10^7$) for analysis of variance and regression partition for grain yield of three groups of populations.....	30
10. Mean grain yield (GY) and test weight (TW) of three groups of triticales populations (each group consisting of two cultivars and one blend made up half from each cultivar) by year, location, and N level.....	31
11. Observed (O) and expected (E) stability parameters [mean, regression coefficient ($\bar{b}$), and deviation mean square (DMS)] for grain yield of three groups of triticales populations, each group consisting of two cultivars and one blend made up half from each cultivar.....	33
12. Mean squares for analysis of variance and regression partition for test weight of three groups of triticales populations.....	35
13. Observed (O) and expected (E) stability parameters [mean, correlation coefficient ($\bar{b}$), and deviation mean square (DMS)] for test weight of three groups of triticales populations, each consisting of two cultivars and one blend made up half from each cultivar.....	36

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Kernel weight of six triticales genotypes vs. environmental mean grain yield.....	23
2. Tiller number of six triticales genotypes vs. environmental mean grain yield.....	25
3. Seed number per tiller of six triticales genotypes vs. environmental mean grain yield.....	29
4. Comparison of regression equations of Florico and IRA triticales.....	41
5. Comparison of the performance of genotype A ($\underline{b} > 1.0$), genotype B ($\underline{b} < 1.0$), and an ideal genotype with $\underline{b} > 1.0$ in above average environments and $\underline{b} < 1.0$ in below average environments.....	42

Abstract of Dissertation Presented to the Graduate School
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Six triticales (XTriticosecale Wittmack) genotypes ('Florida 201', 'Beagle 82', 'Florico', Ira(2)M2AxCml/Ia-Trr, FL7845-TQ-G32-J2, CT3477) were evaluated for mean performance and environmental stability of grain yield (GY), kernel weight (KW), tiller number m^{-2} (TN), plant height (PH), and test weight (TW). Three 1:1 mechanical seed blends (Florida 201 + Beagle 82, Florida 201 + Florico, Beagle 82 + Florico) were tested for mean performance and environmental stability of GY and TW. Sixteen environments (E) including two years (1985-86, 1986-87), two locations (Quincy-- $30^{\circ} 35'$ N Lat, Marianna-- $30^{\circ} 46'$ N Lat), and four N topdress levels (0, 55, 110, 165 kg ha^{-1}) were tested. Analysis of variance and linear regression techniques were applied to the data from the six genotypes and each individual blend combination (the blend and both component cultivars).

Significant genotype (G) effects were observed for all traits. Among the 6 genotypes, significant GE interactions

and differences among genotypes in their linear response (b) to E were observed for all traits. Differences among genotypes for deviation mean squares (DMS) were observed for GY, TN, PH, and TW. No association was found between stability parameters (b and DMS) for GY and the same parameters for PH or TW. Means and b values for GY, KW, and PH were positively correlated. Stability of individual yield components (KW and TN), rather than yield component compensation, seemed to be the major factor in GY stability.

Florida 201 + Florico yielded approximately equal to its higher yielding component, Florico. Other blends had yields intermediate between their component cultivars. Significant GE effects on GY and TW were observed in two of the blend combinations. All blend combinations exhibited differences among populations in b values for GY while one blend combination exhibited differences in b values for TW. Beagle 82 + Florico had a lower DMS than the component average, while Florida 201 + Beagle 82 had a higher DMS than the component average. The use of blends appeared to be a desirable method to enhance yield and environmental stability. However, not all blends showed enhanced performance.

INTRODUCTION

Triticale (XTriticosecale Wittmack) is a man-made small grain species which combines the high grain yield potential of wheat with the broad environmental adaptability and high lysine content of rye. Early triticales were produced by crossing and chromosome doubling of hexaploid wheat (Triticum aestivum L.) and rye (Secale cereale L.), but progeny of these crosses were generally meiotically unstable. After techniques were developed to excise and artificially culture immature embryos, it became possible to produce hexaploid triticale by crossing and chromosome doubling tetraploid wheat (Triticum turgidum L. var durum L.) and rye. Currently, all commercially acceptable cultivars are hexaploid (Varughese et al., 1987).

Triticale has not been tested extensively in the southeastern United States, but excellent potential for human and animal feed production has been shown in preliminary trials (Barnett and Luke, 1979; Kalmbacher et al., 1987; Meyer et al., 1987). 'Beagle 82', the first cultivar recommended for grain production in the area, was released in 1982 (Barnett et al., 1982). By 1985, over 12,000 ha of Beagle 82 were grown in the Florida-Georgia-Alabama area.

'Florida 201', released in 1985, is more productive and has a higher test weight than Beagle 82. Over a six-year period, Florida 201 triticale has yielded at the same level as 'Florida 301', a leading wheat cultivar in Florida (Calhoun and Barnett, 1986).

Little is known, however, regarding the response of triticale genotypes to the diverse environmental conditions encountered in this region. Florida is marginal for small grain production because of many factors including large yearly fluctuations in temperature and precipitation during the winter months. Thus, it is necessary that cultivars be adapted to a broad range of environments.

Selection among genotypes in a crop improvement program is based primarily on performance in breeding nurseries and yield tests on research stations. Such tests are normally conducted under intensive management which may or may not exist in the environment where the cultivar will ultimately be grown. A genotype which gives excellent performance under very favorable conditions often is not the best genotype when grown under less favorable conditions due to genotype x environment interactions. Selection based on environmental stability as well as mean performance can ensure that cultivars which are released will perform adequately under a wide range of growing conditions.

Numerous measures of stability and methods of analysis have been developed to deal with genotype x environment

interactions [e.g. ecovalence, stability index, multi-criteria clustering, and independent environmental measurement proposed by Wricke (1962), Langer et al. (1979), Lefkovitch (1985), and Freeman and Perkins (1971), respectively]. While most stability analysis methods are based on the linear regression of genotype performance on some measure of environmental value, the regression technique proposed by Breese (1969) and others is the best known and most widely used. For the Breese (1969) analysis, yield (or other parameters) of each genotype tested is regressed on an environmental index which is the mean of all genotypes in a specific environment. Three values are used to represent the genotypic response over all environments: 1) overall mean, 2) regression coefficient ($\bar{b}$)--the genotypic response to the environment attributable to linear regression which is predictable, and 3) deviation mean square (DMS)--the deviation of the genotypic response from linear regression which can be considered unpredictable.

From linear regression analysis, a desirable cultivar would have a high mean yield, regression coefficient approaching unity, and DMS equal to zero. A genotype with $\bar{b} < 1.0$ may be undesirable because it would not respond well to better environments or improved management practices with increased yield. In addition, very low $\bar{b}$ values are often associated with low yield (Eberhart and Russell, 1966). On the other hand, a genotype with $\bar{b}$ much greater than 1.0 would

be undesirable because it would be subject to severe yield losses when growing conditions were unfavorable. A small DMS value, indicating predictable response to environment, would be desirable.

Verma and Chahal (1978) proposed an "ideal" genotype which would be relatively insensitive to unfavorable environments but would be responsive to favorable environments. Such a genotype would have $b < 1.0$ in unfavorable environments and $b \geq 1.0$ in favorable environments.

The use of multilines, or mechanical seed blends of two or more genotypes has been proposed as a method of improving the environmental stability of yield and other quantitative traits by increasing the genetic heterogeneity of the resulting population (Pfahler and Linskens, 1979; Singh and Bains, 1984; Norden et al., 1986). Most studies of multiline performance have shown that genetic diversity does not necessarily insure enhanced stability. Rather, each proposed blend must be tested in a number of environments. The stability of triticale blends has not been examined.

Few stability analyses of triticale grain yield have been reported; all found significant genotype x environment interactions and identified lines which were both high yielding and stable (Sandha et al., 1980; Kaltsikes, 1971; Sapra, 1985; and Sinha et al., 1986). However, most of these studies were conducted outside the southeastern United States

using material unadapted to this region. Knowledge of the grain yield stability of genetic material adapted to this area would facilitate the development of high yielding, stable cultivars.

Even less is known regarding stability of other characters in triticale, such as plant height and test weight, or the relationships among stability parameters for these traits. An understanding of these relationships would help breeders develop effective strategies for improving stability of these traits.

The response pattern of yield components (kernel weight, tiller number per unit area, and kernel number per tiller) which results in the desired grain yield response pattern is also poorly understood. There is considerable debate as to whether stable grain yield is a result of stable yield components or a result of compensatory shifts in yield component levels as proposed by Grafius (1956). More information on the relationship between grain yield stability and stability of yield components would be desirable.

The present study was undertaken to evaluate the mean performance and environmental stability of representative triticale cultivars and advanced breeding lines for grain yield, kernel weight, tiller number, plant height, and test weight. Broad sense heritability estimates for these traits also were determined. In addition, mean performance and

environmental stability of grain yield and test weight for three mechanical seed blends were determined.

MATERIALS AND METHODS

Three cultivars ('Florida 201', 'Beagle 82', 'Florico'), three advanced breeding lines from the Florida triticales program [Ira(2)M2A-Cml/Ia-Trr (IRA), FL7845-TQ-G32-J2 (FL7845), CT3477], and the three possible two-way blends of the cultivars (i.e. Florida 201 + Beagle 82, Florida 201 + Florico, Beagle 82 + Florico) were tested. Blends were composed of a mechanical mixture of an equal number of viable seeds from both component cultivars. All triticales genotypes were hexaploid and had a spring growth habit.

Entries were tested in two cropping years (1986 and 1987) at two Florida locations (Quincy--30° 35' N Lat, Marianna--30° 46' N Lat). A uniform seeding rate of 360 viable seed m⁻² was used in all environments. Planting dates at Quincy were 11 December 1985 and 18 December 1986 for the cropping years 1986 and 1987, respectively. Marianna planting dates were 20 December 1985 and 4 February 1987 for the cropping years 1986 and 1987, respectively. The Quincy plantings were irrigated as needed. Pre-plant or early post-plant fertilizer was broadcast mechanically on all plots at a rate of 25, 22, and 62 kg ha⁻¹ of N, P and K, respectively.

Experimental units consisted of 6 rows 20 cm apart and 3.6 m long, trimmed to 3.0 m before harvest. Plots were arranged in a randomized complete block of three replications with four N topdress levels (0, 55, 110, and 165 kg ha⁻¹ of N as ammonium nitrate, applied during the tillering stage) as main plots and genotypes or populations as subplots.

Plant height (PH) and tiller number (TN) were determined prior to harvest. Grain yield (GY) was determined by combine harvest of entire subplots. Kernel weight (KW) was based on weight of a 200 seed sample from each subplot. Test weight (TW) was not measured at Marianna in 1987 due to insufficient seed from many plots. Kernel number per tiller (KN) was calculated from GY, KW, and TN.

Analysis of Pure Lines

Analyses of variance (AOV) and linear regressions were calculated for GY, KW, TN, PH, and TW of the six pure lines (three cultivars and three breeding lines).

The AOV for all characters except TW included 16 environments (E) [4 N topdress levels (N) x 2 locations (L) x 2 years (Y)] as well as the main and interaction effects of N, L and Y, all tested with the main plot error. For the analysis of TW, three location-year combinations (Quincy 1986, Marianna 1986, Quincy 1987) were considered three sites (S). For TW, the AOV included 12 E (4 N x 3 S) and the effects S, N, and SN, all tested with the main plot error.

For all characters measured, the effects of genotype (G) and its interactions were tested with the subplot error.

Linear regressions of individual genotype performance vs. environmental means were used to partition genotype x environment (GE) effects into effects due to heterogeneity of slopes and deviations from linear regressions as proposed by Breese (1969). Significance of heterogeneity and deviation effects were tested with the subplot error. Regression AOV was performed for each genotype separately to test significance of individual DMS. All regression coefficients ($\bar{b}$) were tested for significant difference from 1.0 using t -tests.

Simple correlation coefficients ($df=4$) were calculated for mean vs. $\bar{b}$ and DMS for all parameters measured and for GY stability ($\bar{b}$ and DMS) vs. stability of KW, TN, PH, and TW. For each genotype, simple correlation coefficients ($df=14$) among KW, TN, and KN were calculated, and KW, TN, and KN were regressed against environmental means for GY.

Adjusted values for KW, TN, and KN were calculated by dividing KW, TN, or KN for each genotype at each environment by the corresponding environmental mean. Simple correlation coefficients among adjusted values for KW, TN, and KN were then calculated for each genotype.

The environments were divided into two subsets, as proposed by Verma and Chahal (1978), one which represented favorable or above average environments and one which

represented poor or below average environments. Linear regressions were calculated for each genotype in both subsets. A genotype with $\bar{b} < 1.0$ would be desired in poor environments, whereas a genotype with $\bar{b} > 1.0$ would be desired in favorable environments. A genotype which had $\bar{b} < 1.0$ in poor environments but $\bar{b} \geq 1.0$ in favorable environments would be considered ideal for a broad range of environments.

Broad sense heritability was estimated for GY, KW, TN, PH, and TW by dividing the total phenotypic variance (sum of variances of G, E, and GE) into the variance of G (Falconer, 1983).

Analysis of Blends

Analysis of variance and linear regressions were calculated for GY and TW of three groups of populations involving blends: Group 1 = Florida 201, Beagle 82, and Florida 201 + Beagle 82; Group 2 = Florida 201, Florico, and Florida 201 + Florico; Group 3 = Beagle 82, Florico, and Beagle 82 + Florico. Sources of variation and F tests in the AOV and regression partition for each group were the same as described above for the analysis of pure lines. For each group, genotypic performance was regressed on the environmental means of the three populations involved, and the GE interaction was partitioned into heterogeneity and deviations effects. Significance of DMS and $\bar{b}$ values were tested as described above for pure lines. Expected values for

stability parameters (mean, b, DMS) of each blend were the mean of the corresponding values of the two component cultivars.

RESULTS

Appendix Tables A-1, A-2, A-3, A-4, A-5, and A-6 present means (over three replications) for GY, KW, TN, KN, PH, and TW, respectively, of each genotype or blend in sixteen environments.

Stability of Pure Lines

Grain Yield

The AOV and regression partition for GY are shown in Table 1. Environmental indices (i.e. environmental means) used in linear regressions are presented in Table 2. Genotype means differed significantly and ranged from 2550 kg ha⁻¹ for Florico to 1460 kg ha⁻¹ for FL7845 (Table 3).

Environment had a highly significant ($P < 0.01$) effect on GY with environmental means ranging from 3610 kg ha⁻¹ in 165 kg ha⁻¹ N plots at Quincy in 1987 to 230 kg ha⁻¹ in 0 kg ha⁻¹ N plots the same year at Marianna (Table 2). The effects of Y and L represented uncontrollable E effects and were highly significant ($P < 0.01$) as were the various interaction effects among the environmental factors (Table 1). The mean square for L was the largest for this trait. Nitrogen topdress level was a management practice and thus represented a

Table 1. Mean squares for the analysis of variance and regression partition for grain yield (GY), kernel weight (KW), tiller number (TN), and plant height (PH).

Source	df	GY ^a	KW	TN ^b	PH
Genotype (G)	5	8,732**	1,296**	817**	7,641**
Environment (E)	15	24,320**	680**	357**	2,199**
Year (Y)	1	23,726**	1,667**	1,924**	5,236**
Location (L)	1	278,109**	7,892**	820**	8,633**
YL	1	7,369**	99	249*	6,044**
N level (N)	3	12,790**	13	191**	2,790**
YN	3	770**	44	92	226
LN	3	1,583**	14	243**	213
YLN	3	1,910**	22	193**	91
GE	75	410**	10**	96**	98**
Variance partition					
GY	5	1,627**	15**	342**	151**
GL	5	2,015**	62**	203**	587**
GYL	5	582**	5	366**	273**
GN	15	272**	8	100**	37
GYN	15	203**	6	23	25
GLN	15	49	5	30	37
GYLN	15	137*	3	27	53
Regression partition					
Heterogeneity	5	1,481**	67**	122**	623**
Deviation	70	333**	6	94**	60*
Replication ^c	8	793**	33	25	388*
Main plot error ^d	24	217	20	36	136
Subplot error ^e	160	98	5	20	40

*, ** Significant at the 0.05 and 0.01 probability level, respectively.

^a Mean square $\times 10^{-3}$.

^b Mean square $\times 10^{-2}$.

^c Replication within years and locations.

^d Used to test significance of E, Y, L, N, YL, YN, LN, YLN, Replication.

^e Used to test significance of G, GE, GY, GL, GN, GYL, GYN, GLN, GYLN, Heterogeneity, Deviation.

Table 2. Mean grain yield (GY), kernel weight (KW), tiller number (TN), plant height (PH), and test weight (TW) of six triticales genotypes by year, location, and N level. Values represent environmental indices used in regression analysis.

Year ^a	Location	N level ^b	GY	KW	TN	PH	TW
		kg ha ⁻¹	kg ha ⁻¹	mg seed ⁻¹	no. m ⁻²	cm	g L ⁻¹
1986	Quincy	0	2720	46	271	97	700
		55	3360	43	336	101	710
		110	3160	43	371	102	700
	Marianna	165	3480	45	334	103	690
		0	1060	36	295	89	680
		55	1620	37	318	104	680
1987	Quincy	110	1780	34	308	100	670
		165	1690	34	330	103	650
		0	1850	40	267	91	650
	Marianna	55	2850	42	282	103	660
		110	3400	41	307	105	660
		165	3610	41	324	108	650
LSD _{0.05}		0	230	29	254	68	--
		55	890	30	280	87	--
		110	750	29	245	86	--
		165	700	29	190	84	--
			350	3	5	9	10

^a Year harvested.

^b Topdress N applied.

Table 3. Stability parameters [mean, regression coefficient ($\bar{b}$), and deviation mean square (DMS)] for grain yield (GY), kernel weight (KW), tiller number (TN), plant height (PH), and test weight (TW) of six hexaploid triticale genotypes.

Stability parameter	Genotype	GY kg ha ⁻¹	KW mg seed ⁻¹	TN no. m ⁻²	PH cm	TW g L ⁻¹
Mean	Florida 201	2290	42	288	102	690
	Beagle 82	1730	39	240	103	660
	Florico	2550	43	299	106	720
	IRA	2440	31	362	79	670
	FL7845	1460	40	262	104	650
	CT3477	1970	31	317	80	670
	LSD .05	150	1	21	3	10
$\bar{b}_a$	Florida 201	1.05	1.06	0.83	0.95	1.10
	Beagle 82	0.97	0.96	1.42**	1.10	1.07
	Florico	1.27**	1.33**	0.50*	1.19	1.15
	IRA	1.02	0.77**	0.69	0.53**	0.96
	FL7845	0.83**	1.05	1.24	1.48**	0.48**
	CT3477	0.88*	0.83**	1.31	0.67**	1.20*
	LSD .05	0.05	0.07	0.21	0.11	0.11
DMS ^b	Florida 201	126,453	4.830	1,116	40.32	252**
	Beagle 82	215,139**	1.803	4,621**	27.27	150
	Florico	363,582**	6.165	10,041**	34.29	256**
	IRA	222,369	5.964	12,073**	59.16	498**
	FL7845	244,779**	6.999	9,520**	103.26	749**
	CT3477	516,867**	3.504	9,866**	38.55	115

a *, ** Significantly different than 1.0 at the 0.05 and 0.01 probability levels, respectively.

b *, ** Significantly different than 0.0 at the 0.05 and 0.01 probability levels, respectively.

controllable E effect. The influence of N was highly significant, but in most cases, GY did not respond to N topdress levels above 55 kg ha⁻¹ (Table 2). However, at Quincy in 1987, GY in the 110 kg ha⁻¹ N plots was significantly greater than in 55 kg ha⁻¹ N plots.

The GE effect was also highly significant, and G interacted significantly with all environmental factors and most interactions among environmental factors (Table 1). In the regression partition, the effect of heterogeneity of slopes was highly significant ($P < 0.01$) with b values ranging from 0.83 for FL7845 to 1.27 for Florico (Table 3). Individual DMS were also significantly different (Table 1) with DMS values ranging from 126,453 for Florida 201 to 516,867 for CT3477 (Table 3).

Mean GY was significantly ($P < 0.05$) correlated with corresponding b values ($r = 0.83$, $df = 4$), but not DMS ($r = 0.02$, $df = 4$).

Table 4 presents regression coefficients calculated for each genotype in above and below average environments. Only Florida 201 fit the criteria for an "ideal" genotype over a broad range of environments (i.e. $b > 1.0$ in above average environments and $b < 1.0$ in below average environments).

The broad sense heritability estimate for GY ($\pm$ standard error) was 0.11 ± 0.03 .

Table 4. Means and regression coefficients ($\bar{b}$) for grain yield of six triticales genotypes in above average and below average environments.

Genotype	Environment set			
	Above average		Below average	
	Mean	$\bar{b}$	Mean	$\bar{b}$
	--kg ha ⁻¹ --		--kg ha ⁻¹ --	
Florida 201	3380	0.96	1200	0.69*
Beagle 82	2680	0.91	770	1.00
Florico	3890	1.06	1210	0.88
IRA	3340	1.31*	1530	1.37*
FL7845	2310	0.58**	610	0.79**
CT3477	2730	1.19	1210	1.27
LSD _{0.05}	140	0.17	100	0.13

*, ** Significantly different than 1.0 at the 0.05 and 0.01 probability levels, respectively.

Kernel Weight

The AOV and environmental indices for KW are presented in Tables 1 and 2, respectively. The effect of G was highly significant (Table 1) with genotype means ranging from 31 mg seed⁻¹ for CT3477 to 43 mg seed⁻¹ for Florico (Table 3).

The AOV for KW indicated highly significant ($P < 0.01$) effects of E, Y, and L (Table 1). In the absence of significant interaction effects, comparisons can be made between years and locations. KW was consistently higher at the Quincy location and in 1986 (Table 2). Means over the location-year combinations ranged from 44 mg seed⁻¹ at Quincy in 1986 to 29 mg seed⁻¹ at Marianna in 1987.

The effect of GE was highly significant ($P < 0.01$) although G interacted only with Y and L (Table 1). The regression partition indicated that genotypes differed significantly ($P < 0.01$) in b values but not in DMS (Table 1). The b values ranged from 0.77 for IRA to 1.33 for Florico (Table 3).

Mean KW was significantly ($P < 0.05$) correlated with b ($r = 0.88$, $df = 4$), but not DMS ($r = 0.15$, $df = 4$). The correlation coefficient between b for KW and b for GY was relatively high ($r = 0.65$, $df = 4$), but not statistically significant ($P > 0.05$) (Table 5). KW had a significant positive correlation with KN in all genotypes and with TN in Florida 201 and Beagle 82 (Table 6). Correlation coefficients were not significant for adjusted KW vs. adjusted TN or adjusted KN (Table 7).

Table 5. Simple correlation coefficients between stability parameters [regression coefficient ($\bar{b}$) and deviation mean square (DMS)] for grain yield (GY) and other traits [kernel weight (KW), tiller (TN), plant height (PH), and test weight (TW)].

Trait	Stability parameter	GY	
		$\bar{b}$	DMS
KW	b	0.65	-0.06
	DMS	0.18	-0.11
TN	b	-0.83*	0.15
	DMS	-0.03	0.56
PH	b	-0.02	-0.21
	DMS	-0.53	-0.18
TW	b	0.52	0.33
	DMS	-0.32	-0.35

* Significantly different than 0.0 at the 0.05 probability level, df=4.

Table 6. Simple correlation coefficients among kernel weight (KW), tiller number (TN), and kernel number per tiller (KN) by genotype.

Genotype	KW vs. TN	KW vs. KN	TN vs. KN
Florida 201	0.53*	0.85**	0.30
Beagle 82	0.61*	0.83**	0.30
Florico	0.23	0.89**	0.11
IRA	-0.10	0.60*	-0.39
FL7845	0.39	0.79**	0.41
CT3477	0.27	0.71**	0.21

*, ** Significantly different than 0.0 at the 0.05 and 0.01 probability levels, respectively, df=14.

Table 7. Simple correlation coefficients among kernel weight (KW), tiller number (TN), and kernel number per tiller (KN) (as a proportion of their environmental means) by genotype.

Genotype	KW vs. TN	KW vs. KN	TN vs. KN
Florida 201	0.19	0.24	-0.39
Beagle 82	-0.13	-0.31	-0.10
Florico	-0.34	-0.12	-0.60*
IRA	0.01	-0.11	-0.46
FL7845	0.31	-0.18	0.33
CT3477	-0.21	-0.23	-0.24

* Significantly different than 0.0 at the 0.05 probability level, df=14.

Regression of KW vs. environmental mean for GY (Fig. 1) indicated that KW of all genotypes increased with increasing GY, but genotypes differed in their rate of increase.

The broad sense heritability ($\pm$ standard error) for KW was 0.41 ± 0.26 .

Tiller Number

The AOV and environmental indices for TN are presented in Tables 1 and 2, respectively. Genotypes differed significantly in TN and ranged from 240 tillers m^{-2} for Beagle 82 to 362 tillers m^{-2} for IRA (Table 3).

TN was significantly ($P < 0.01$) influenced by E, Y, L, and N, and by the interaction effects LN and YLN (Table 1). The effect of YL was significant at $P < 0.05$. Environmental means ranged from 190 to 371 tillers m^{-2} (Table 2).

The effect of GE was highly significant and G interacted significantly ($P < 0.01$) with Y, L, YL, and N (Table 1). Regression partition indicated highly significant ($P < 0.01$) effects of heterogeneity and deviation (Table 1). Regression coefficients ranged from 0.50 for Beagle 82 to 1.42 for Florico, and DMS ranged from 12,073 for IRA to 1,116 for Florida 201 (Table 3).

Regression coefficients tended to decrease ($r = -0.57$, $df = 4$) and DMS tended to increase ($r = 0.57$, $df = 4$) with increasing mean TN, though correlation coefficients for these relationships were not significant. There was a significant

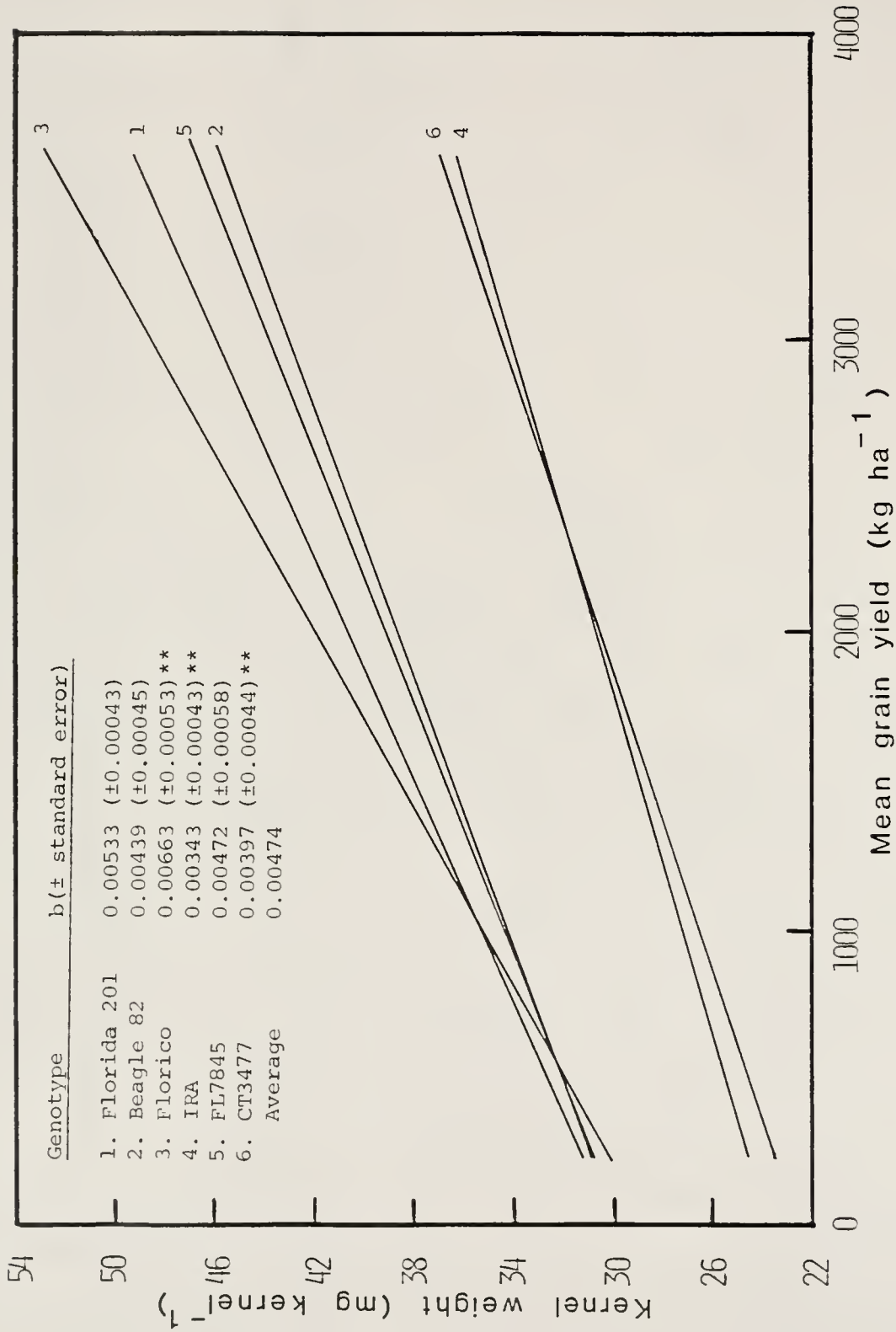


Figure 1. Kernel weight of six triticale genotypes vs. environmental mean grain yield. ** indicates b is significantly different than average at the 0.01 probability level.

negative relationship for $\bar{b}$ of GY vs. $\bar{b}$ of TN (Table 5). TN and KN were not significantly correlated in any genotype, though in 5 of 6 genotypes, TN tended to increase with increasing KN (Table 6). The adjusted TN of Florico was negatively correlated with adjusted KN of Florico (Table 7).

Regression of TN vs. environmental means for GY (Fig. 2) indicated that, in all genotypes except IRA, TN increased with increasing mean GY.

The broad sense heritability estimate ($\pm$ standard error) for TN was 0.27 ± 0.11 .

Plant Height

The AOV and regression partition for PH are shown in Table 1. Genotype means ranged from 79 cm for IRA to 106 cm for Florico (Table 3).

The effect of E was highly significant ($P < 0.01$) with environmental means ranging from 68 to 108 cm (Table 2). The main effects of Y, L, and N were also highly significant as was the YL interaction (Table 1). The effect of N was independent of Y and L. With the exception of Quincy in 1986, PH in 0 kg ha^{-1} N plots was significantly ($P < 0.05$) less than in plots receiving topdress N (Table 2).

The GE effect was highly significant ($P < 0.01$), but G interacted only with Y, L, and YL (Table 1). Regression partition indicated highly significant ($P < 0.01$) effects of

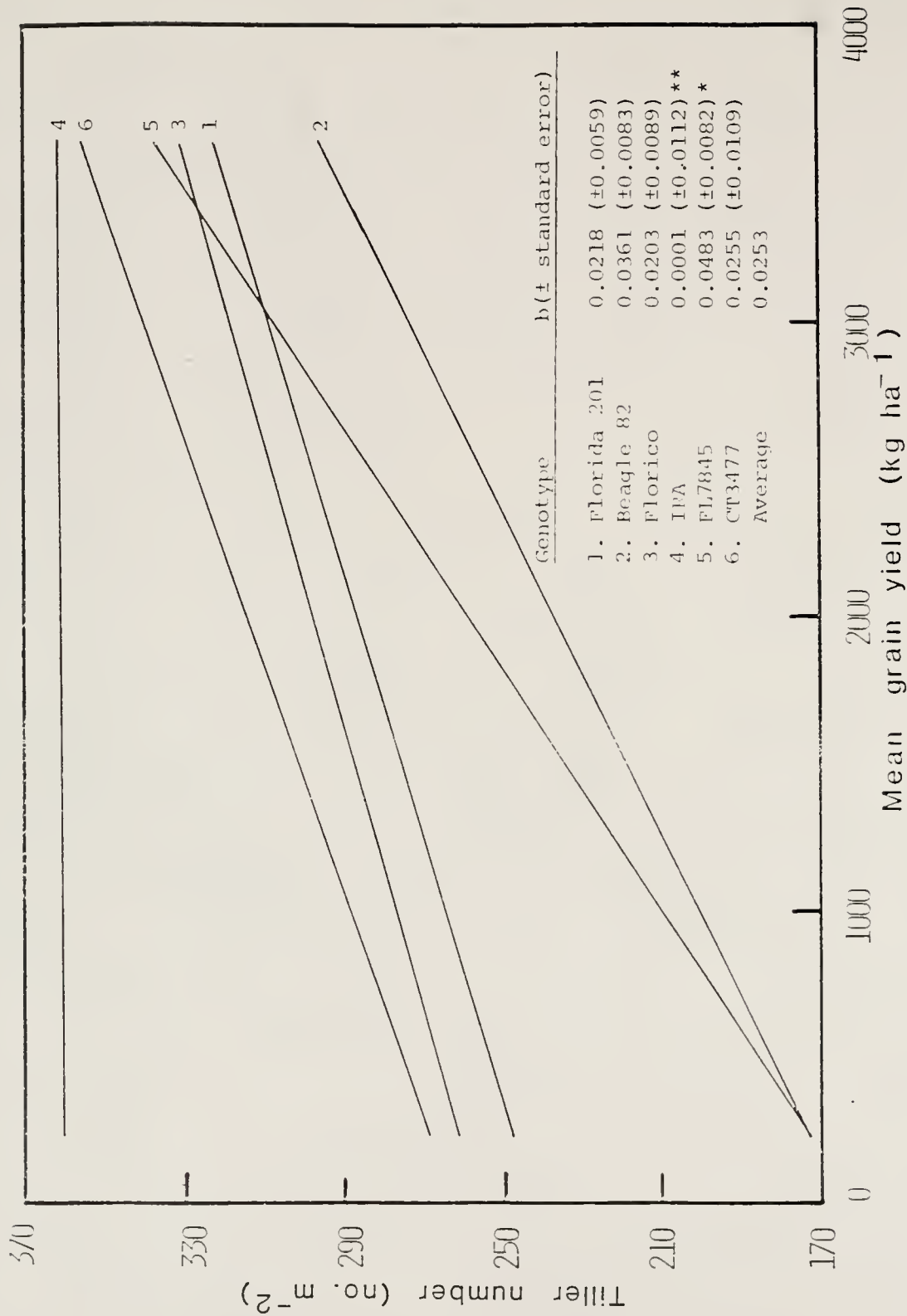


Figure 2. Tiller number of six triticale genotypes vs. environmental mean grain yield. *, ** indicates b is significantly different than average at the 0.05 and 0.01 probability levels, respectively.

heterogeneity and deviation (Table 1). Regression coefficients ranged from 0.53 for IRA to 1.48 for FL7845, and DMS ranged from 27.27 for Beagle 82 to 103.26 for FL7845 (Table 3).

Mean PH was significantly ($P < 0.05$) correlated with $\bar{b}$ ($r = 0.88$, $df = 4$), but not DMS ($r = 0.05$, $df = 4$). Stability parameters for PH were not significantly correlated with stability parameters for GY (Table 5).

The broad sense heritability estimate ($\pm$ standard error) for PH was 0.55 ± 0.31 .

Test Weight

The AOV and regression partition for TW are presented in Table 8. Environmental indices used in regression analyses are shown in Table 2. Genotype means ranged from 650 g L⁻¹ for FL7845 to 720 g L⁻¹ for Florico (Table 3).

As shown in Table 8, the effect of E and all environmental component effects were highly significant ($P < 0.01$). Environmental means ranged from 650 to 710 g L⁻¹ (Table 2).

The effect of GE was highly significant ($P < 0.01$) as were the interactions of G with S and N (Table 8). The regression partition indicated that heterogeneity and deviation effects were also highly significant (Table 8). Regression

Table 8. Mean squares for the analysis of variance and regression partition for test weight of six triticale genotypes.

Source	df	Mean Square
Genotype (G)	5	21,478**
Environment (E)	11	8,564**
Site (S)	2	38,917**
N level (N)	3	2,971**
SN	6	1,243**
GE	55	469**
Variance partition		
SG	10	1,743**
NG	15	315**
SNG	30	121
Regression partition		
Heterogeneity	5	1,130**
Deviation	50	403**
Replication ^a	6	280
Main plot error ^b	18	130
Subplot error ^c	120	134

** Significant at the 0.01 probability level.

^a Replication within sites.

^b Used to test significance of E, S, N, SN, Replication.

^c Used to test significance of G, GE, GS, GN, GSN, Heterogeneity, Deviation.

coefficients ranged from 0.48 for FL7845 to 1.20 for CT3477, and DMS ranged from 115 for CT3477 to 498 for IRA (Table 3).

The $\bar{b}$ values for TW tended to increase with increasing $\bar{b}$ value for GY (Table 5) and with increasing mean TW ($r=0.59$, $df=4$) but neither relationship was statistically significant.

The broad sense heritability estimate ($\pm$ standard error) was 0.44 ± 0.24 .

Kernel Number per Tiller

Regression of KN vs. environmental means for GY indicated that, in all genotypes, KN increased with higher yielding environments, but the rate of increase differed among genotypes (Fig. 3).

Stability of Blends

Grain Yield

Table 9 presents the AOV and regression partition for the three groups of triticale populations (P) which included blends (i.e. Group 1: Florida 201, Beagle 82, and Florida 201 + Beagle 82; Group 2: Florida 201, Florico, and Florida 201 + Florico; Group 3: Beagle 82, Florico, and Beagle 82 + Florico). Environmental indices used in linear regressions are shown in Table 10. In all groups, GY was significantly ($P<0.01$) influenced by P (Table 9). The blend in Group 2 yielded equal to its higher yielding component, Florico,

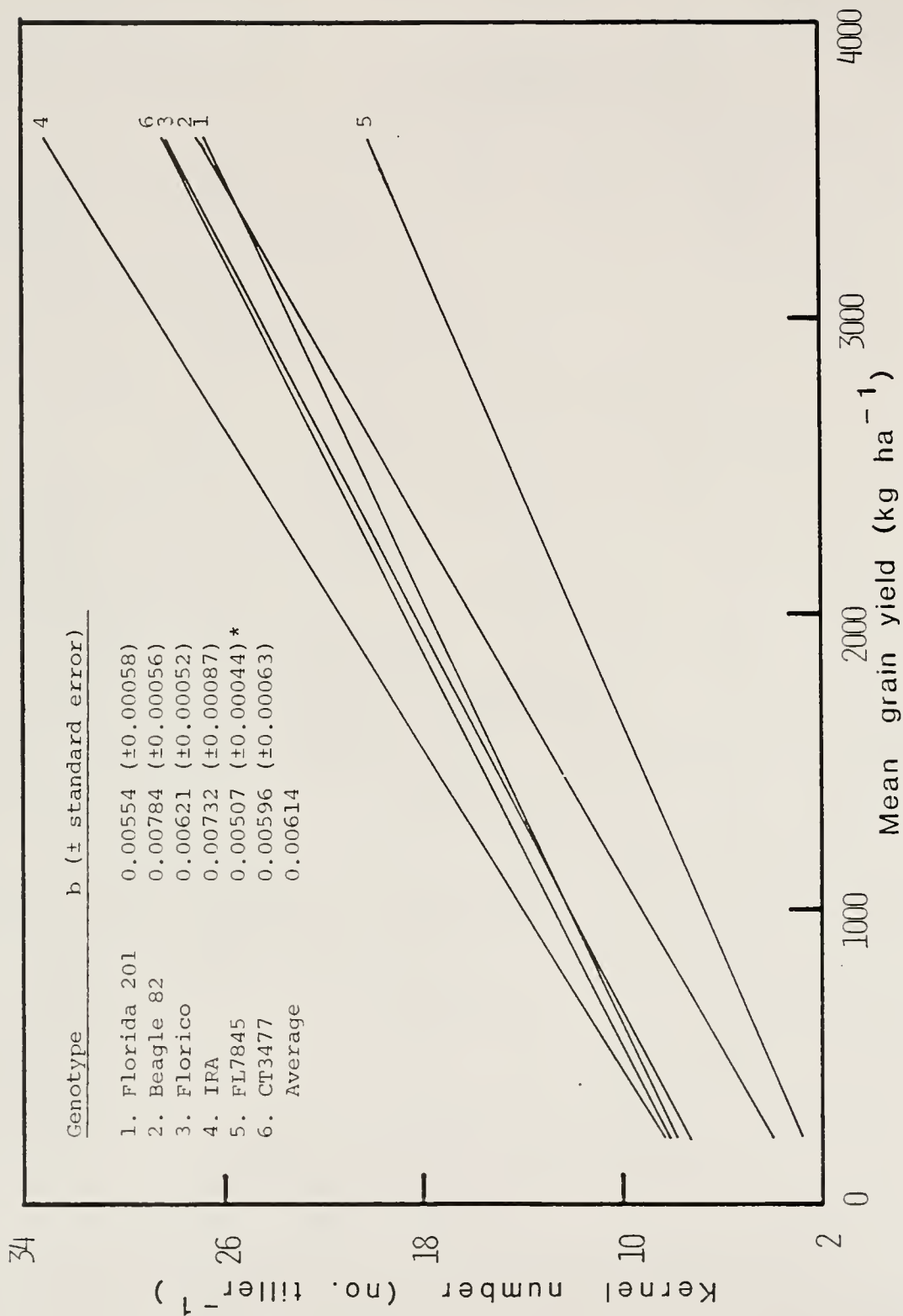


Figure 3. Seed number per tiller of six triticale genotypes vs. environmental mean grain yield. * indicates b is significantly different than average at the 0.05 probability level.

Table 9. Mean squares ($\times 10^{-3}$) for analysis of variance and regression partition for grain yield of three groups of populations. Each group consisted of two cultivars and one blend made up half from each cultivar (Group 1: 'Florida 201', 'Beagle 82', and Florida 201 + Beagle 82; Group 2: Florida 201, 'Florico', and Florida 201 + Florico; Group 3: Beagle 82, Florico, and Beagle 82 + Florico).

Source	df	Group		
		1	2	3
Population (P)	2	3,813**	1,269**	9,082**
Environment (E)	15			
Year (Y)	1	11,580**	17,200**	16,000**
Location (L)	1	20,414**	3,453**	8,460**
YL	1	125,628**	214,877**	202,381**
N level (N)	3	654*	6,362**	4,397**
YN	3	6,219**	5,815**	4,890**
LN	3	74	923**	523*
YLN	3	954**	818**	882**
	3	394*	1,347**	883**
PE	30	307**	151	373**
Variance partition				
PY	2	1,772**	186	1,572**
PL	2	1,313**	751**	1,983**
PYL	2	85	360*	712**
PN	6	156	51	104
PYN	6	208*	45	153
PLN	6	57	65	28
PYLN	6	59	164	170*
Regression partition				
Heterogeneity	2	210**	912**	1,726**
Deviation	28	314**	97	279*
Replication ^a	8	508**	764**	395*
Main plot error ^b	24	122	151	127
Subplot error ^c	64	82	103	73

*, ** Significant at the 0.05 and 0.01 levels, respectively.

^a Replication within years and locations.

^b Used to test significance of E, Y, L, N, YL, YN, LN, YLN, Replication.

^c Used to test significance of P, PE, PY, PL, PN, PYL, PYN, PLN, PYLN, Heterogeneity, Deviation.

Table 10. Mean grain yield (GY) and test weight (TW) of three groups of triticales populations (each group consisting of two cultivars and one blend made up half from each cultivar) by year, location, and N level. Values represent environmental indices used in regressions analysis.

Year ^a	Location	N level ^b	GY			TW		
			Group			Group		
			1	2	3	1	2	3
1986	Quincy	kg ha ⁻¹	-----kg ha ⁻¹ -----			-----g L ⁻¹ -----		
		0	2620	3340	3090	700	740	720
		55	3290	3790	3580	710	740	730
	Marianna	110	3390	3490	3420	700	740	710
		165	3650	3940	3750	690	730	700
1987	Quincy	0	1040	1150	1060	670	700	690
		55	1590	1740	1540	700	700	690
		110	1800	1800	1590	660	700	680
	Quincy	165	1600	1770	1610	650	690	700
		0	1660	2620	2220	640	670	660
		55	2290	3620	3420	650	680	670
	Marianna	110	3070	4330	3850	650	690	670
		165	3170	4440	3850	650	670	670
		0	230	410	290	---	---	---
		55	850	1210	880	---	---	
		110	690	1020	730	---	---	
		165	700	910	560	---	---	
		LSD .05	370	410	380	10	8	10

^a Year harvested.

^b N topdress level.

while the blends in Groups 1 and 3 had GY intermediate between their component cultivars (Table 11).

The grain yield of all groups was significantly influenced by E, Y, L, and N (Table 9). In most cases, GY did not respond to N levels greater than 55 kg ha⁻¹, however, at Quincy in 1987, GY in 110 kg ha⁻¹ N plots was significantly greater than in 55 kg ha⁻¹ N plots (Table 10). Interactions among environmental factors were all significant at $P < 0.05$ or 0.01 with the exception of the YN interaction in Group 1 (Table 9). Environmental means ranged from 230 to 3650, from 410 to 4440, and from 290 to 3850 kg ha⁻¹ in Groups 1, 2, and 3, respectively (Table 10). The highest yielding environment for Group 1 was at Quincy in 1986, while the highest yielding environment for Groups 2 and 3 was at Quincy in 1987.

The interaction PE was significant ($P < 0.01$) in groups 1 and 3 (Table 9). Although the PE interaction was not significant in Group 2, the interaction effects PL and PYL were significant ($P < 0.01$ and $P < 0.05$, respectively). P did not interact significantly ($P > 0.05$) with N in any group. The regression partition indicated that the effect of heterogeneity was highly significant in all groups (Table 9). The deviation effect was significant ($P < 0.05$) in Groups 1 and 3. The greatest range in $\bar{b}$ values was observed in Group 3 (0.83 for Beagle 82 to 1.12 for Florico) (Table 11). No DMS value in Group 2 was significantly different from zero. DMS

Table 11. Observed (O) and expected (E) stability parameters [mean, regression coefficient ($\bar{b}$), and deviation mean square (DMS)] for grain yield of three groups of triticales populations, each group consisting of two cultivars and one blend made up half from each cultivar.

Group	Population	Mean		$\bar{b}$		DMSb	
		0	E	0	E	0	E
1		---kg ha ⁻¹ ---					
	Florida 201	2290		1.06		293,104	
	Beagle 82	1730		1.01		77,403	
	Blend 1	1970	2007	0.93	1.04	261,441**	185,254
	LSD.05	130		0.06			
2	Florida 201	2290		0.89**		48,267	
	Florico	2550		1.10**		65,697	
	Blend 2	2590	2420	1.01	0.95	80,529	56,982
	LSD.05	150		0.04			
	Beagle 82	1730		0.83**		274,803**	
3	Florico	2550		1.12**		213,464	
	Blend 3	2380	2139	1.05	0.98	71,049	244,134*
	LSD.05	130		0.04			

a ** Significant from 1.0 at the 0.01 probability level.

b ** Significant from 0.0 at the 0.01 probability level.

for the blend in Group 1 and Beagle 82 in Group 3 were significantly ($P < 0.01$) greater than zero.

Test Weight

The AOV and regression partition for Groups 1, 2, and 3 are presented in Table 12. The effect of P was highly significant ($P < 0.01$) in all groups (Table 12). Florico had the highest TW, 720 g L^{-1} , and Beagle 82 had the lowest, 660 g L^{-1} (Table 13). The blends in all groups consistently had TW close to the mean TW of their component cultivars.

The effects of E, S, and N were significant ($P < 0.01$) in all groups (Table 12). The interaction SN was significant at $P < 0.05$ in Groups 1 and 2, and at $P < 0.01$ in Group 3. Environmental mean ranges were 640 to 710, 670 to 740, and 660 to 730 g L^{-1} in Groups 1, 2, and 3, respectively (Table 10). In all groups, the highest TW was observed in 55 kg ha^{-1} N plots at Quincy in 1986, and the lowest TW was observed in 0 kg ha^{-1} plots at Quincy in 1987.

Highly significant ($P < 0.01$) PE interaction was observed only in Group 3 (Table 12). The PE interaction in Group 2 was significant at $P < 0.05$. In all groups, however, P interacted significantly ($P < 0.01$) with S. The regression partition indicated that Group 2 had a significant ($P < 0.05$) deviations effect with DMS values ranging from 50 to 158 (Table 13). Group 3 had highly significant ($P < 0.01$) heterogeneity and deviation effects (Table 12) with b values

Table 12. Mean squares for analysis of variance and regression partition for test weight of three groups of triticales populations. Each group consisted of two cultivars and one blend made up half from each cultivar (Group 1: 'Florida 201', 'Beagle 82', and Florida 201 + Beagle 82; Group 2: Florida 201, 'Florico', and Florida 201 + Florico; Group 3: Beagle 82, Florico, and Beagle 82 + Florico).

Source	df	Group		
		1	2	3
Population (P)	2	9,384**	7,272**	32,642**
Environment (E)	11	5,657**	6,113**	4,577**
Site (S)	2	28,423**	31,818**	21,894**
N level (N)	3	874**	780**	1,128**
SN	6	460*	210*	529**
PE	22	168	144*	311**
Variance partition				
PS	4	341*	332**	919**
PN	6	126	71	284*
PSN	12	131	133	122
Regression partition				
Heterogeneity	2	80	49	431**
Deviation	20	177	154*	299**
Replication ^a	6	103	111	132
Main plot error ^b	18	147	58	89
Subplot error ^c	48	133	77	122

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

^a Replication within sites.

^b Used to test significance of E, S, N, SN, Replication.

^c Used to test significance of P, PE, PS, PN, PSN, Heterogeneity, Deviation.

Table 13. Observed (O) and expected (E) stability parameters [mean, correlation coefficient ($\bar{b}$), and deviation mean square (DMS)] for test weight of three groups of triticales populations, each consisting of two cultivars and one blend made up half from each cultivar.

Group	Population	Mean		$\bar{b}$		DMS	
		0	E	0	E	0	E
1		-----g L ⁻¹ -----					
	Florida 201	690		0.99		161**	
	Beagle 82	660		0.95		111	
	Blend 1	670	671	1.07	0.97	82	136
	LSD .05	10		--			
2	Florida 201	690		0.95		158**	
	Florico	720		1.01		50	
	Blend 2	710	701	1.04	0.98	116	104
	LSD .05	10		--			
	Beagle 82	660		1.06		94	
3	Florico	720		1.12		226**	
	Blend 3	690	685	0.82	1.09	279**	160
	LSD .05	10		0.09			

** Significant from 0.0 at the 0.01 probability level.

ranging from 0.82 for the blend to 1.12 for Florico and DMS ranging from 94 for Beagle 82 to 279 for the blend (Table 13).

DISCUSSION

Pure Lines

For most traits, the wide range of environmental means and relatively uniform distribution across the range provided a basis for comparing the response of genotypes to different environments. A possible exception was PH where seven environments were in the 100 to 104 cm range, while the other nine environments were distributed more uniformly between the 68 and 108 cm extremes. It should be noted that the large L effect, seen particularly for GY, was due to differences in planting date and water management as well as edaphic differences between Quincy and Marianna.

Genetic variation for a trait is required in order to alter that trait by phenotypic selection. Therefore, to improve GY performance and stability, variation among genotypes must exist for GY mean, *b* value, and/or DMS. In this study, genotypes were found to differ for all three stability parameters. Other workers have also found triticales genotypes differing in GY mean, *b* value, and DMS (Sandha et al., 1980; Sapra, 1985; Sinha et al., 1986). Thus it should be possible to select for enhanced GY stability in triticales.

Eberhart and Russell (1966) have described a desirable genotype as one which combines high mean yield with average b value and low DMS. A positive correlation among stability parameters would seem to preclude the combination of high yield with average b value and low DMS. In this study, b values and means for GY were positively correlated. A positive relationship between b value and mean for GY has been reported by some workers (Fischer and Maurer, 1978; Baihaki et al., 1976; Eberhart, 1969), while others (Gama and Hallauer, 1980) found no such relationship. The association between b values and mean performance of GY observed here and reported by other researchers could result, in part, from the nature of the analysis and the genotypes involved. Since observed yield cannot fall below zero, the intercept of a linear regression will not be very much less than zero. Thus, it would be difficult to envision a situation where low mean yield would be associated with a large b value. The low b values thus associated with low yielding genotypes could influence the correlation between b and mean. However, the critical issue is whether some (however few) genotypes combine high yield with average b value. In this study, one genotype, IRA, was high yielding and had an average b value as well as a low DMS. Other workers have also found triticales genotypes which combined high yield and desired stability (Kaltsikes, 1971; Sandha et al., 1980; Sapra,

1985). Thus, selection can apparently be made for stability without sacrificing high yield.

A graphical presentation of regression equations of Florico and IRA (Fig. 4) illustrate the significance of this type of analysis. Florico would be expected to yield more than IRA in high yielding environments, such as in breeding yield nurseries. Thus, IRA could be easily overlooked if no consideration is given to production in a broad range of environments. IRA would be expected to yield higher than Florico in low yielding environments. No yield data are available for commercial triticales production in Florida. However, wheat and triticales yield levels are similar in experimental plots, and commercial wheat production in the state averages about 2000 kg ha⁻¹ (Florida Department of Agriculture, Division of Marketing, 1986). In such environments, IRA and Florico would be expected to yield about equal and other considerations such as disease resistance, plant height, or grain quality would become more important. Further, IRA had a low DMS, whereas Florico had a large DMS.

Verma and Chahal (1978) have proposed an alternative to the idea that $b=1.0$ is the desired level of linear response. Given two genotypes with equal mean yield and different b values, the genotype with the higher b value would be higher yielding in favorable environments and lower yielding in less favorable environments (Fig 5.) A theoretical "ideal"

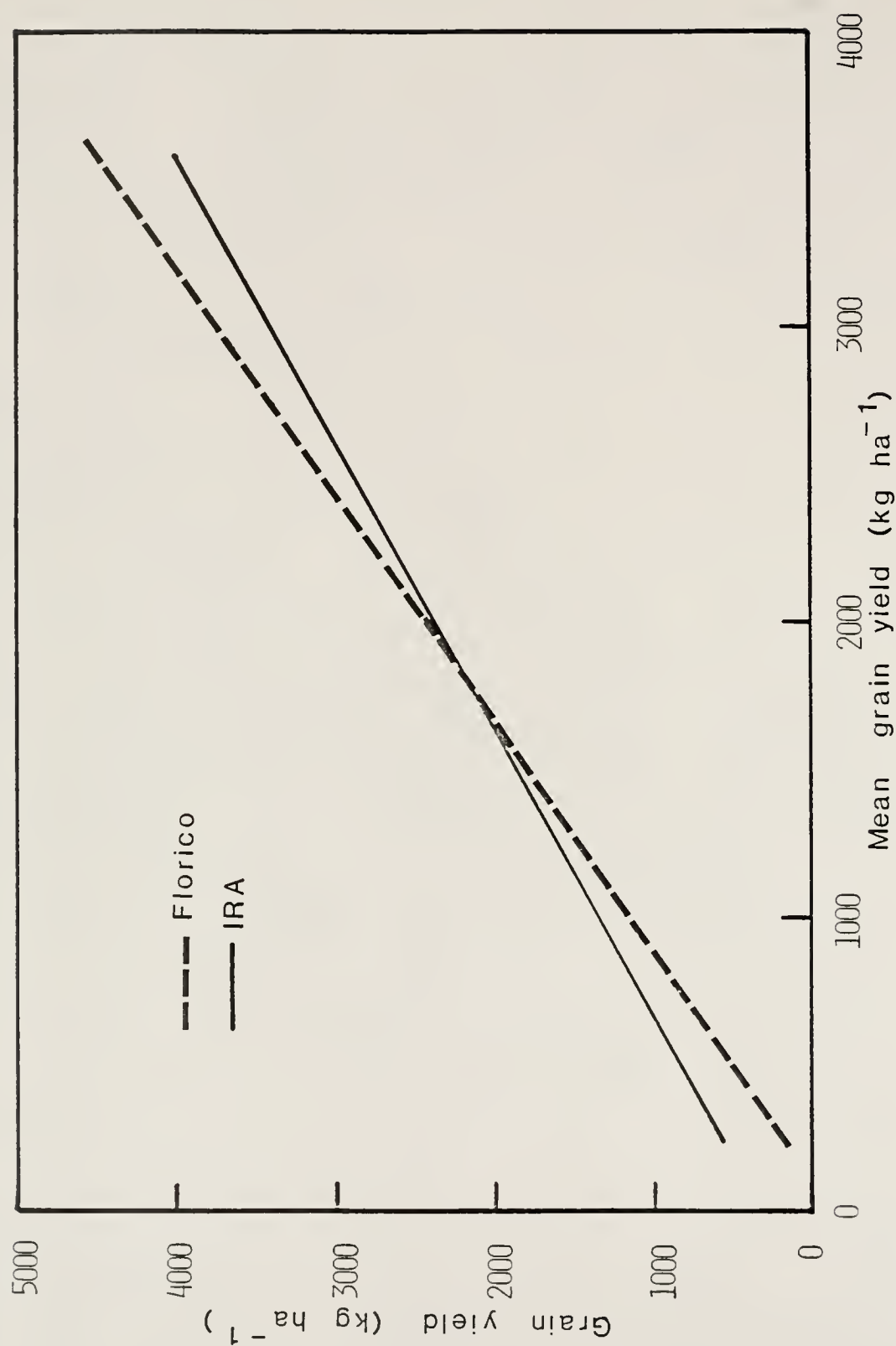


Figure 4. Comparison of regression slopes of 'Florico' and IRA triticale. Equations are presented in Table 3.

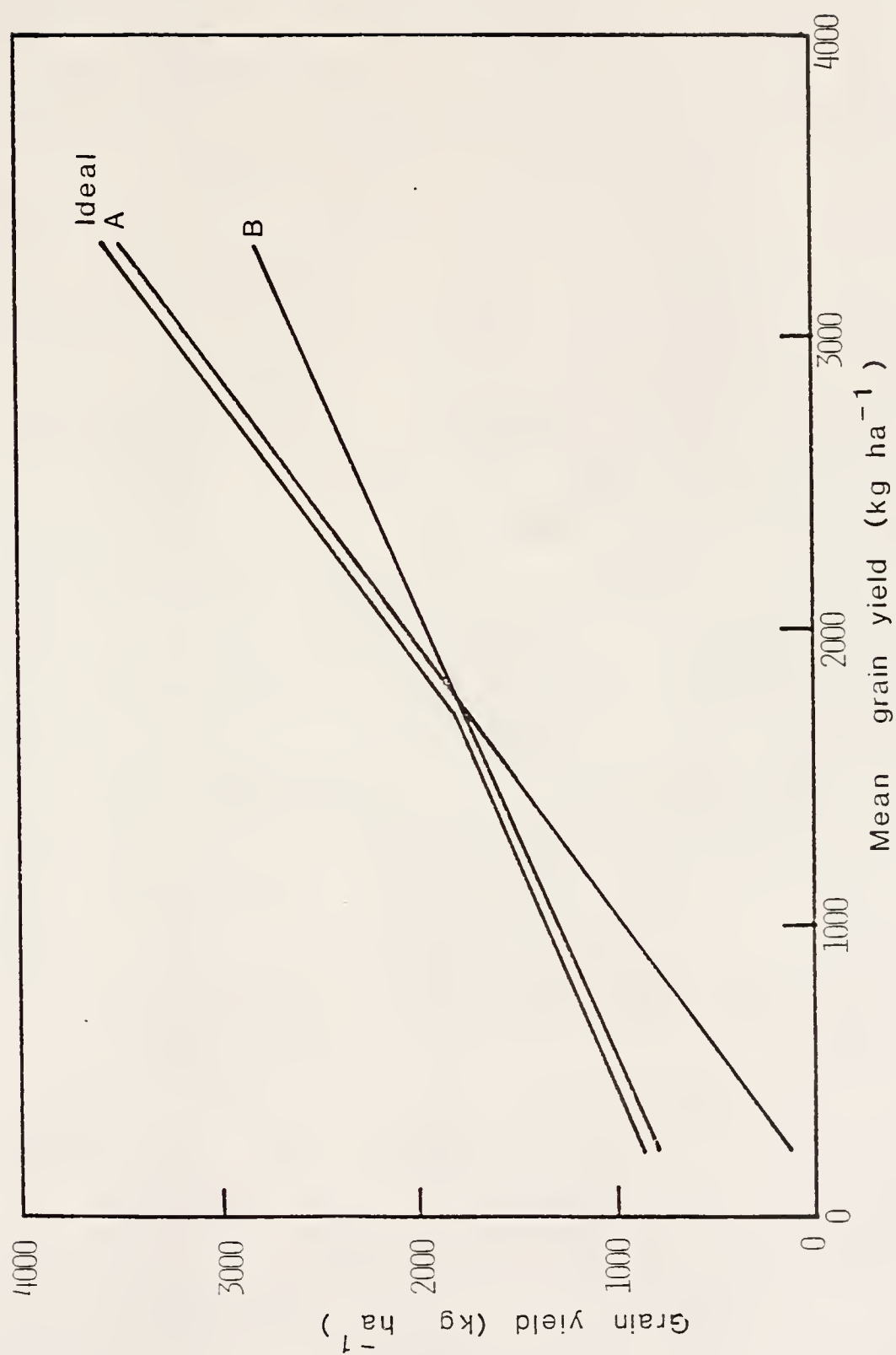


Figure 5. Comparison of the performance of genotype A ($\bar{b} > 1.0$), genotype B ($\bar{b} < 1.0$), and an ideal genotype with $\bar{b} > 1.0$ in above average environments and $\bar{b} < 1.0$ in below average environments. (Adapted from Verma and Chahal, 1978.)

genotype would have a low $\underline{b}$ value in less favorable environments, but a high $\underline{b}$ value in favorable environments. To identify genotypes which had this response pattern, linear regressions were calculated for genotypes in this study in two environmental subsets as described by Verma and Chahal (1978). Florida 201 exhibited the ideal $\underline{b}$ values proposed by Verma and Chahal (1978) (i.e. $\underline{b} \geq 1.0$ in above average environments and $\underline{b} < 1.0$ in below average environments). However, its mean yield was surpassed by Florico in above average environments and by IRA in below average environments. Thus, the advantage Florida 201 had in terms of $\underline{b}$ values was moderated by its low mean yield relative to Florico and IRA. The present example does not detract from the value of this approach since it is theoretically possible to find genotypes which combine the desired $\underline{b}$ values with high mean performance in both sets of environments.

It has been reported that $\underline{b}$ value for GY is related to yield and plant height (Laing and Fischer, 1977; Purvis, 1973). While a positive correlation between $\underline{b}$ value for GY and mean GY was observed in the present study, there was no such association between $\underline{b}$ value for GY and mean PH. The genotypes with the highest and lowest $\underline{b}$ values (Florico and FL7845, respectively) were both tall, and both of the short genotypes (IRA and CT3477) had average or below average $\underline{b}$ values. Sinha et al. (1986) likewise found no relationship between $\underline{b}$ values for GY and mean PH in triticales. An

association between these parameters would be expected in a set of genotypes where $\underline{b}$ value and mean for GY are highly correlated and there is a close association between yield potential and plant height, as was the case when Laing and Fischer (1977) and Purvis (1973) compared semi-dwarf wheats to their taller counterparts.

While $\underline{b}=1.0$ is generally accepted as desirable for GY (Eberhart and Russell, 1966), this is not the case for quality traits such as TW. For quality traits, a minimum $\underline{b}$ value, in addition to low DMS, would be the goal since a uniform product, regardless of production environment, is generally desired. Unfortunately, the only genotype which had a relatively low $\underline{b}$ value for TW (FL7845) had the lowest mean TW. Beagle 82 and CT3477 had low DMS for TW and low mean TW.

A low $\underline{b}$ value and DMS=0.0 for PH would also be desirable since uniform plant height, even across variable field conditions, would enhance acceptability and facilitate mechanical harvest. Low mean values were again associated with low $\underline{b}$ values and the two short genotypes, IRA and CT3477, had $\underline{b}<1.0$.

Although it is accepted that an average $\underline{b}$ value (i.e. $\underline{b}=1.0$) for GY is desirable, there seems to be no clear understanding of how, in terms of yield components, this level of linear response is achieved. Low $\underline{b}$ values for GY could be achieved in a genotype by two means: 1) yield

components could resist change or 2) yield component levels could change in a compensating manner such that the final product remained relatively constant.

Grafius (1956) has presented a geometrical interpretation of yield component compensation in widely adapted genotypes. Reports by other researchers are quite conflicting in this regard. Vaid et al. (1985) and Rathnaswamy and Jagathesan (1982), working with dry bean and sesame, respectively, found that b values for fruiting body number were significantly correlated with b values for GY. Saeed and Francis (1983) found that b for GY was significantly correlated with b for seeds m^{-2} in all grain sorghum genotypes tested and with b for KW in late maturing genotypes. They concluded that stability for yield components contributed to GY stability. Heinrich et al. (1983) also concluded that yield component compensation was not the major mechanism of GY homeostasis in grain sorghum. In hexaploid wheat, Talukdar and Bains (1982) observed a significant positive correlation between b values for GY and b values for KW. However, they concluded that responsiveness of KN and TN to changes in environment was the chief means by which GY levels were maintained across diverse growing conditions.

Singh and Bains (1984) found no association between b values for GY and b values for yield components in chickpea. Bains and Gupta (1972) and Fatih (1987) likewise found no

such association in hexaploid wheat or wheat-Agropyron derivatives, respectively. These three reports attributed low b values for GY to yield component compensation.

If yield component compensation was the mechanism of maintaining GY across diverse environments, a decrease in one yield component should be accompanied by an increase in another yield component. In general, this was not the case for genotypes tested in this study. All genotypes showed a positive correlation between KW and KN. In addition, two genotypes showed a positive correlation between KW and TN. Only IRA gave any indication of yield component compensation (i.e. a negative, nonsignificant correlation between KW and TN, and between TN and KN).

Given that all yield components were adversely affected in less favorable environments, the data were examined for the possibility of a relative increase in one yield component accompanying a relative decrease in another. When correlation coefficients were calculated for adjusted values yield components, there was an apparent trend for yield component compensation, but only the r value for adjusted TN vs. adjusted KN of Florico was significant. In FL7845, the genotype with the lowest b value for GY, positive, though nonsignificant ($P < 0.05$), correlation coefficients for adjusted KW vs. adjusted TN and adjusted TN vs. adjusted KN were observed. Therefore, yield component compensation did

not seem to be the major factor controlling GY responsiveness.

The $\bar{b}$ value for GY would then appear to depend on the $\bar{b}$ values of individual yield components. In the present study, $\bar{b}$ values for GY and KW had a relatively high, though nonsignificant, correlation coefficient. Responsiveness for GY and TN were significantly correlated, but surprisingly, the correlation was negative.

Since environments were ranked differently for GY, KW, and TN, the functional relationships between GY and yield components could be better understood by regressing KW, TN, and KN against environmental means for GY rather than against their own environmental means. Florico, the genotype with the highest $\bar{b}$ value for GY, had a $\bar{b}$ value for KW vs. mean GY significantly ($P < 0.01$) greater than average (Fig. 1), but TN vs. mean GY (Fig. 2) and KN vs. mean GY (Fig. 3) $\bar{b}$ values were equal to the average. Therefore, the high $\bar{b}$ value for GY of Florico was due to the high $\bar{b}$ value of KW vs. mean GY. FL7845, the genotype with the lowest $\bar{b}$ value for GY, had above average $\bar{b}$ value for TN vs. mean GY and below average $\bar{b}$ value for KN vs. mean GY. Therefore, the relatively low $\bar{b}$ value for GY of this genotype was due to the tendency of KN to remain constant despite environmental conditions. IRA had remarkably constant TN across environments (Fig. 2), though the genotype showed an average $\bar{b}$ value for GY. For IRA, the $\bar{b}$ value for KN vs. mean GY (Fig. 3) was above average, though

not statistically so. In the case of IRA, the low b value of TN vs. mean GY was counterbalanced by the high b value for KN vs. mean GY. Thus, b values for GY seemed to depend on the b value of one or more yield components vs. mean GY, and genotypes differed in which yield component(s) had the major impact.

Heritability estimates depend greatly upon the range of genetic variation in the material tested and upon the magnitude of environmental variance. Broad sense heritability (H^2) estimates reported here were lower than estimates reported for triticale elsewhere in the literature, due, probably, to the large range of environments sampled. Kamboj and Mani (1982) reported H^2 estimates of 0.91, 0.54, 0.72, and 0.74 for GY, KW, TN, and PH, respectively. Banik and Islam (1984) reported H^2 estimates of 0.66 and 0.71 for TN and PH, respectively.

Blends

Genetic diversity in a population has the potential to enhance yield and yield stability, particularly when extreme environmental fluctuations occur or in the presence of sporadic disease or insect outbreaks. In such situations, plants affected by adverse conditions can be compensated for by neighboring plants which are more tolerant to environmental pressure. Population diversity also has the potential to improve utilization of available resources when

component individuals differ in their environmental requirements. Yet, acceptance of commercial cultivars in most species requires uniformity for such characters as plant height and maturity, especially for machine harvest.

The three blends considered here would meet accepted uniformity standards. Although all cultivars were visually similar in growth habit and maturity, and no disease or insect pressure was evident, two of the combinations apparently benefited from genetic diversity in terms of GY. The blends, Florida 201 + Florico and Beagle 82 + Florico yielded higher than the mean of their component cultivars, and Florida 201 + Florico yielded equal to its higher yielding component. Both of these blends approached unity regression more closely than their component cultivars, and Beagle 82 + Florico had a lower DMS than expected. The common cultivar in these two blends was Florico. Florico had the highest yield in this study, but also had an extremely high b value. The interaction of Florico with the lower yielding and more stable cultivars, Florida 201 and Beagle 82, resulted in enhanced performance in their blends.

Genetic diversity itself did not ensure enhanced performance. One blend (Florida 201 + Beagle 82) did not yield higher than the mean of its component cultivars, and the blend had a significant DMS, even though both component cultivars had $DMS=0.0$. Pfahler and Linskens (1979) also found that only certain blends approached desired stability

($\bar{b}$ =1.0 and DMS=0.0) more closely than their component pure lines. Singh and Bains (1984) found no blend which yielded equal to its higher yielding component, and only a few blends equaled or exceeded their component lines in terms of stability.

While the use of blends appears to offer a means of enhancing yield performance over a range of environments, it cannot be assumed that increased genetic diversity will necessarily have the desired effect. Each proposed combination must be tested. As Pfahler and Linskens (1979) have pointed out, blends which include high yielding, rather stable lines would be more likely to perform well in diverse environments.

APPENDIX
DATA TABLES

Table A-1. Grain yield in kg ha⁻¹ of nine triticale populations in sixteen environments (averaged over three replications).

Year:	1985-86						1986-87									
	Quincy				Marianna		Quincy				Marianna					
Location:	165	110	55	0	165	110	55	0	165	110	55	0				
N level: ^a Population ^b																
Florida 201	3,861	3,315	3,484	3,022	1,478	1,627	1,623	1,178	3,959	3,905	3,187	2,279	1,066	1,059	1,198	372
Beagle 82	3,400	3,131	3,189	2,592	1,379	1,516	1,322	818	2,521	2,733	2,516	1,362	291	279	457	112
Florico	4,045	3,500	4,021	3,198	1,889	1,651	1,601	1,223	4,889	4,791	3,821	2,833	848	1,034	1,162	308
IRA	3,601	3,608	3,702	3,183	2,487	2,560	2,064	1,265	4,282	3,586	3,145	1,615	1,106	1,151	1,285	314
FL7845	2,266	1,700	2,575	2,107	972	1,086	1,290	723	3,002	2,779	2,383	1,699	136	257	321	91
CI3477	3,692	3,728	3,204	2,244	1,946	2,244	1,810	1,122	3,015	2,580	2,052	1,334	756	722	906	192
Blend 1	3,461	3,732	3,316	2,944	1,788	1,664	1,496	869	3,726	3,774	3,164	2,008	634	827	939	401
Blend 2	3,922	3,648	3,875	3,803	1,957	2,137	2,010	1,050	4,456	4,296	3,859	2,748	801	978	1,270	564
Blend 3	3,803	3,763	3,527	3,489	1,563	1,593	1,695	1,150	4,138	4,031	3,924	2,477	540	872	1,033	455

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha⁻¹.

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

Table A-2. Kernel weight in mg kernel^{-1} of nine triticale populations in sixteen environments (averaged over three replications).

Year:	1985-86						1986-87									
	Quincy				Marianna		Quincy				Marianna					
Location:	165	110	55	0	165	110	55	0	165	110	55	0				
N level ^a :																
Population ^b																
Florida 201	50.5	48.3	48.7	49.4	36.7	37.3	38.5	38.3	46.5	45.1	47.0	44.7	33.8	33.1	34.7	31.6
Beagle 82	46.1	45.0	44.0	48.4	36.7	36.6	39.3	38.1	40.3	43.3	43.3	41.8	31.3	30.2	31.5	31.1
Florico	54.5	49.9	49.0	54.5	40.0	39.2	41.1	38.4	48.0	48.5	46.9	43.7	32.1	32.3	31.7	29.4
IRA	36.0	35.5	35.7	37.8	27.9	27.3	31.1	34.6	33.8	32.9	34.2	31.4	23.6	24.8	24.8	24.2
FL7845	45.9	43.8	47.1	48.8	36.6	33.2	41.7	38.3	41.2	43.8	43.8	44.5	31.3	30.8	31.2	29.6
CI3477	38.0	37.8	34.4	37.8	27.4	27.7	28.2	29.5	32.9	34.4	34.5	32.9	23.2	23.8	24.3	25.7
Blend 1	47.5	52.7	49.2	48.9	36.3	39.4	40.9	36.5	45.8	45.9	45.2	43.7	33.6	35.2	35.4	33.8
Blend 2	52.6	52.9	51.1	53.7	40.1	41.4	41.0	38.1	48.3	50.2	47.0	46.5	32.6	31.3	32.9	30.5
Blend 3	53.5	52.2	46.9	49.4	37.4	38.0	42.1	36.5	49.4	49.5	47.4	46.8	32.1	34.5	29.0	31.9

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha^{-1} .

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

Table A-3. Tiller number m⁻² of nine triticale populations in sixteen environments (averaged over three replications).

Year:	1985-86										1986-87									
	Quincy					Marianna					Quincy					Marianna				
Location:	165	110	55	0	165	110	55	0	165	110	165	110	55	0	165	110	55	0	165	110
N level: ^a population ^b	165	110	55	0	165	110	55	0	165	110	165	110	55	0	165	110	55	0	165	110
Florida 201	308.7	346.0	310.0	248.7	327.0	321.0	305.7	288.0	299.0	303.0	318.7	299.3	318.7	299.3	194.7	237.3	279.7	229.0	194.7	237.3
Beagle 82	286.3	338.0	342.3	264.0	257.0	269.7	314.3	310.0	260.0	247.7	194.3	140.3	194.3	140.3	122.2	133.3	188.7	169.7	122.2	133.3
Florico	232.3	289.3	314.0	247.7	290.3	287.7	294.7	283.7	398.0	370.3	386.7	350.3	386.7	350.3	158.7	273.7	293.7	319.7	158.7	273.7
IRA	457.7	482.7	350.3	347.7	391.0	399.0	371.0	322.3	325.3	352.0	229.3	237.7	229.3	237.7	311.7	391.0	407.7	407.7	311.7	391.0
FL7845	277.7	284.0	374.0	247.3	276.3	241.7	282.0	300.3	329.3	311.7	329.3	333.7	329.3	333.7	97.5	124.9	194.3	188.7	97.5	124.9
CI3477	441.0	484.0	328.3	272.3	438.0	332.3	340.7	266.7	329.7	260.0	232.0	242.0	232.0	242.0	256.0	321.3	314.0	208.7	256.0	321.3
Blend 1	347.7	356.0	337.7	354.7	279.3	274.0	322.7	289.0	310.3	292.0	216.7	228.0	216.7	228.0	164.0	197.3	261.3	229.3	164.0	197.3
Blend 2	302.0	315.7	282.3	250.3	280.7	261.0	307.3	287.7	353.3	325.3	356.0	269.7	356.0	269.7	148.7	203.0	322.7	324.0	148.7	203.0
Blend 3	356.3	325.3	365.7	271.0	299.0	283.7	303.0	283.7	288.0	271.3	290.7	193.0	290.7	193.0	137.5	181.0	212.7	206.7	137.5	181.0

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha⁻¹.

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

Table A-4. Kernel number tiller⁻¹ of nine triticale populations in sixteen environments (averaged over three replications).

Year:	1985-86										1986-87									
	Quincy					Marianna					Quincy					Marianna				
Location:	165	110	55	0	165	110	55	0	165	110	55	0	165	110	55	0				
N level: ^a Population ^b																				
Florida 201	25.03	19.70	23.77	24.73	12.21	13.57	13.60	10.67	28.63	29.20	21.93	18.00	15.87	13.30	12.20	5.17				
Beagle 82	26.07	20.33	21.63	20.23	14.87	15.40	10.70	6.94	24.07	25.67	29.73	23.17	6.87	6.90	8.42	2.27				
Florico	33.17	24.53	26.80	23.63	16.60	14.27	13.04	11.34	25.70	26.83	21.07	19.27	16.70	11.73	12.37	3.24				
IRA	22.77	21.30	29.93	24.33	22.53	23.67	18.18	10.84	38.90	31.27	40.30	22.03	14.77	11.90	12.60	3.27				
FL7845	18.20	14.09	14.73	17.53	9.62	14.07	11.39	6.22	23.03	20.73	16.57	11.52	4.54	6.70	5.33	1.59				
CI3477	23.23	20.63	28.77	21.90	16.03	24.90	18.47	13.79	27.73	29.30	25.60	17.20	12.34	9.41	11.63	3.53				
Blend 1	21.10	19.93	20.50	17.20	17.21	15.37	11.25	8.22	26.60	28.13	33.10	21.03	11.34	12.44	10.42	5.06				
Blend 2	24.93	21.53	27.73	28.43	17.77	19.27	15.63	9.38	26.07	26.53	23.20	22.10	17.53	15.33	12.17	5.86				
Blend 3	20.13	22.07	20.50	26.67	14.11	14.70	13.13	11.29	29.20	29.83	28.43	27.73	12.51	14.20	17.87	6.72				

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha⁻¹.

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

Table A-5. Plant height in cm of nine triticale populations in sixteen environments (averaged over three replications).

Year:	1985-86						1986-87									
	Quincy				Marianna		Quincy				Marianna					
Location:	165	110	55	0	165	110	55	0	165	110	55	0				
N level ^a :																
Population ^b																
Florida 201	106.33	106.33	110.67	108.00	99.73	105.80	110.00	93.90	112.33	114.67	109.67	96.67	87.50	93.33	97.50	74.17
Beagle 82	113.00	113.00	110.67	105.80	107.67	110.80	112.33	97.33	113.00	113.00	114.00	96.67	88.33	90.83	86.67	75.83
Florico	116.33	108.00	113.00	111.33	121.00	115.00	116.00	98.80	116.67	116.67	111.67	103.17	96.50	93.33	94.10	70.83
IRA	83.73	81.13	78.57	78.60	86.10	86.27	84.57	69.17	89.17	81.67	80.00	65.83	76.67	78.33	77.37	65.00
FL7845	115.00	115.67	115.67	103.23	118.33	98.00	111.33	102.27	124.00	120.00	118.00	108.00	81.67	85.83	85.83	65.00
CI3477	82.00	89.70	79.43	76.90	89.70	83.70	87.10	74.30	90.83	83.33	84.17	74.17	73.33	75.00	81.67	60.00
Blend 1	112.33	109.67	112.33	111.67	105.60	111.77	111.33	83.83	114.00	119.00	113.00	99.83	92.50	96.67	93.33	73.33
Blend 2	107.00	109.67	111.33	109.67	116.33	115.00	116.67	91.40	118.67	119.00	114.00	101.50	93.33	99.17	93.33	70.00
Blend 3	115.00	115.67	111.33	107.00	114.00	114.27	116.67	100.57	120.33	117.00	116.33	104.67	93.33	96.67	93.33	75.00

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha⁻¹.

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

Table A-6. Test weight in g L⁻¹ of nine triticale populations in twelve environments (averaged over three replications).

Year:	1985-86								1986-87							
Location:	Quincy				Marianna				Quincy							
	165	110	55	0	165	110	55	0	165	110	55	0				
N level: ^a Population ^b																
Florida 201	714.3	718.7	725.3	720.7	654.0	680.3	684.7	680.0	673.7	671.3	662.7	660.7				
Beagle 82	669.0	676.0	694.0	695.0	646.0	639.3	656.3	660.7	628.7	633.0	641.7	622.0				
Florico	740.3	749.0	755.0	742.7	703.3	716.3	716.3	710.0	684.3	699.3	684.3	678.0				
IRA	671.3	680.0	708.0	686.3	654.0	673.7	692.7	703.7	637.3	648.0	650.0	641.3				
FL7845	637.0	643.7	667.0	678.0	605.0	637.3	641.3	662.7	646.0	654.3	650.0	641.7				
CT3477	686.7	703.7	710.0	695.7	652.0	667.0	667.0	678.0	637.3	644.0	643.7	628.7				
Blend 1	684.3	695.0	708.0	699.3	637.3	667.0	673.7	678.0	660.7	662.7	662.7	650.0				
Blend 2	731.7	736.0	744.7	744.7	697.0	703.3	705.7	707.7	663.0	684.3	688.7	671.3				
Blend 3	690.7	710.0	727.3	725.3	656.3	676.0	690.7	691.0	689.0	682.3	682.0	675.7				

^a Topdress nitrogen (as ammonium nitrate) applied in kg ha⁻¹.

^b Blend 1 = Florida 201 + Beagle 82, Blend 2 = Florida 201 + Florico, Blend 3 = Beagle 82 + Florico.

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BIOGRAPHICAL SKETCH

Steve Calhoun was born in Harlingen, Texas, on 9 October 1957, and raised mainly in the West Texas oilpatch town of Midland. After graduating from Robert E. Lee High School, Steve attended Texas A&M University where he became an Aggie; got acquainted with Mary Diane McDaniel; and completed, with honors, a B.S. in agronomy.

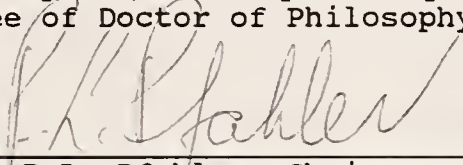
From 1980 to 1982, he worked for the Southern Baptist Foreign Mission Board in Jos, Nigeria, where he taught agriculture in a mission high school, managed the school farm, and corresponded with Diane. Upon his return, Steve worked on a ranch in Southwest Kansas.

In March 1983, Steve and Diane married and moved to Florida where Steve began work on a M.S. degree with Dr. Gordon Prine. In 1985, Steve completed the epic work, "Elephantgrass Performance in a Warm Temperate Environment," and began work on his Ph.D. in plant breeding with Drs. Pfahler and Barnett.

On 12 September 1987, Diane gave birth to their sons, Rossi Rutledge, who was still born, and Heathman Divilbiss, who died shortly after premature birth.

Upon graduation, Steve and Diane plan to move to Texcoco, Mexico, where Steve has a postdoctoral fellowship with Centro International de Mejoramiento de Maiz y Trigo.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Dr. P.L. Pfahler, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



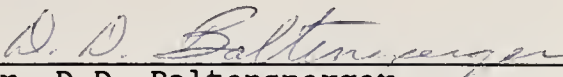
Dr. R.D. Barnett, Cochairman
Professor of Agronomy

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Dr. K. Hinson
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Dr. D.D. Baltensperger
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Dr. D.A. Knauff
Associate Professor of Agronomy

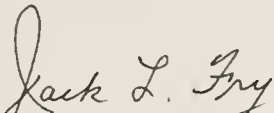
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

April 1988



Dean, College of Agriculture

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